Can a new materials innovation in thin film optical applications be faster and cheaper?

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Labforinvention

Contents

- Introduction:
  - New materials innovation is important for optical applications
  - Materials development is complex and time consuming
- How to enhance the materials research?
  - Current technologies for materials research
  - What can further enhance innovation?
- Case studies
- Summary

New materials innovation is important for optical applications

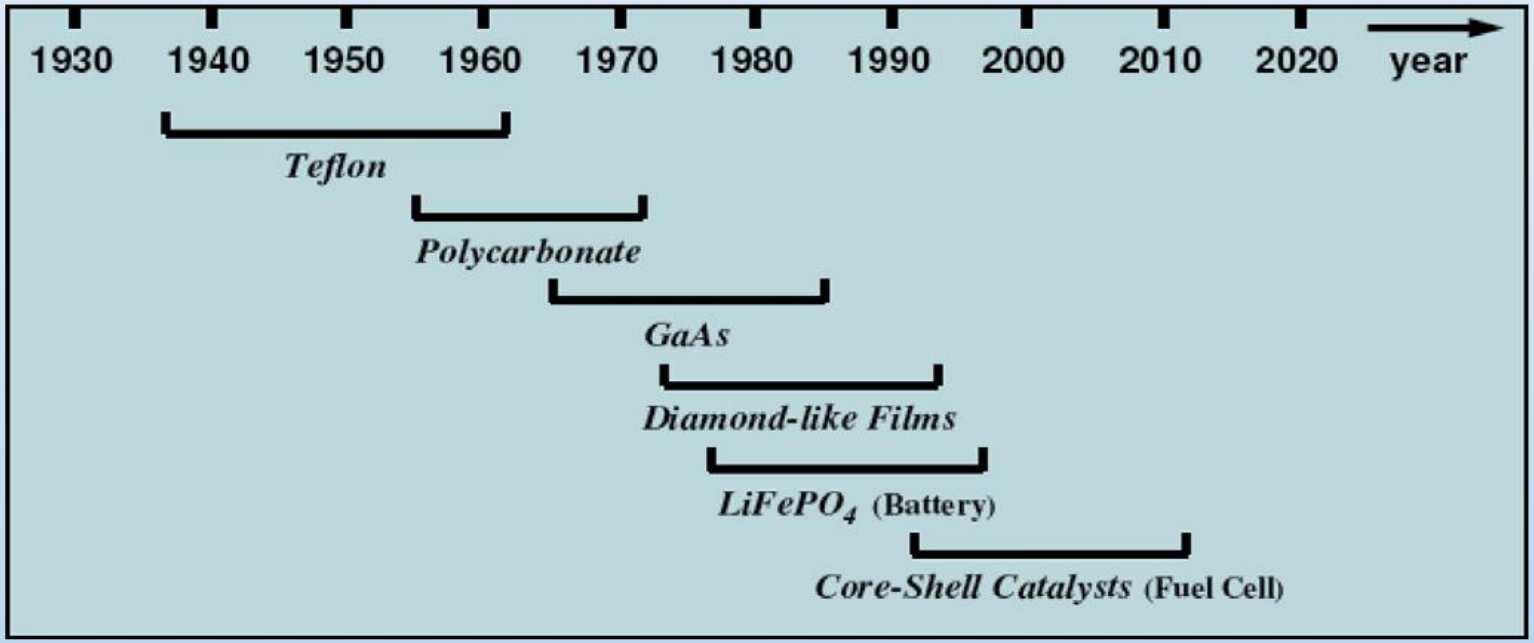
- Cell phone glass coating:
  - Anti-finger print
  - Anti-reflection, anti-glare
  - Anti-scratch ….

- New features for display glass coating

- Wearable display products
- Solar panels
- Others…..

Materials development is complex and time consuming

- Materials development is time consuming
  - It could be 10-20 years from lab discovery to first practical use
- Lab materials screening is complex and time consuming



Example of time frame for bring new materials to market

**ACS Comb. Sci. 2011, 13, 579–633

What can we do ?

- Moore’s law predicts faster, cheaper, more powerful solutions in the future

Moore’s law

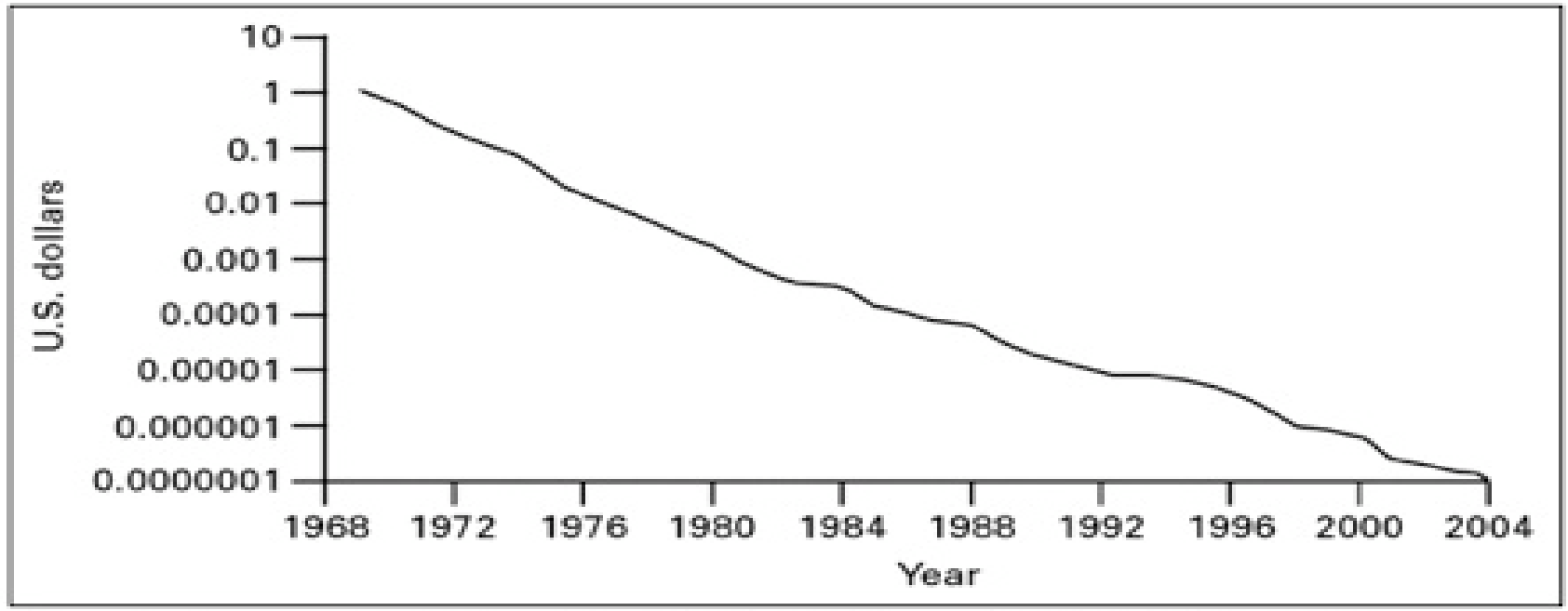
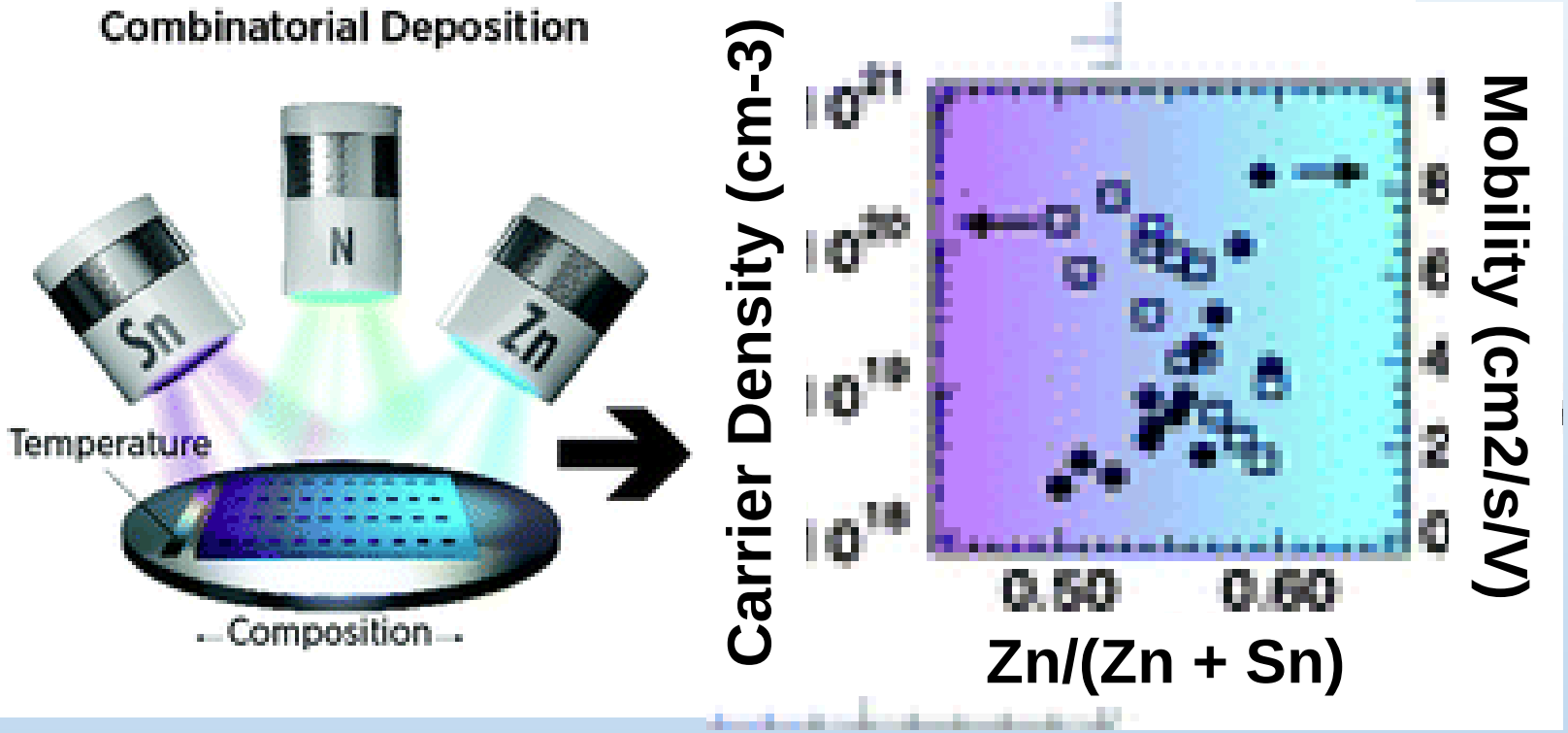


Figure 3. Average price of a transistor (1968–2004). Source: Intel/WSTS, May 2005.

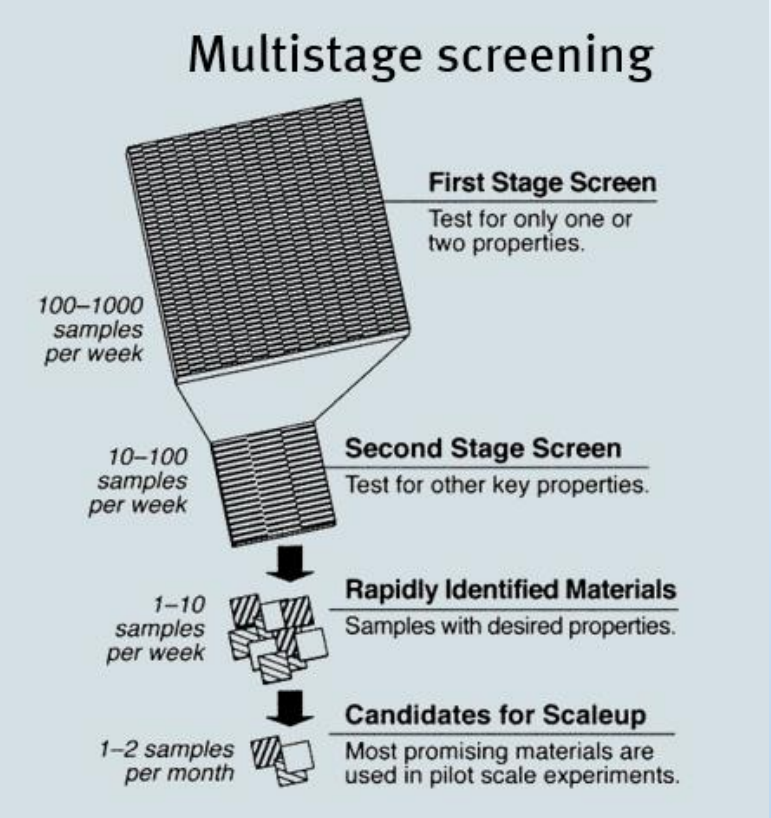
Current Technologies for Materials Research

- Combinatorial is a common technology for materials research



Combinatorial insights into doping control and transport properties of zinc tin nitride

J. Mater. Chem. C, 2015,**3**, 11017-11028



www.win.tue.nl/~adibucch/2DS01/2DS01lec5.ppt Statistics 2 for Chemical Engineering. lecture 5.

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What can further enhance materials innovation?

- "The more brains, the better"
- How can attract more brains (more people) on innovation?
- Can materials innovations be accessible, affordable, and open to more brains (more people)?
- Reducing the threshold on the innovation is a way to attract more brains,
  - Hardware
  - Software
  - Knowledge barrier

cims.ncsu.edu/the-more-brains-the-better/

Can research project threshold be significantly reduced?

- Traditional research project needs
  - PhD lead
  - Millions $ findings
  - Well prepared plan, and complicated funding application procedures
- Could new optical coating prototypes, publications for a project cost at
  - 100 time cheaper?
  - 10-100 time faster?
  - At $10,000 scale?
- Don’t need ten year training as a PhD?

Affordable equipment (Moore's law)

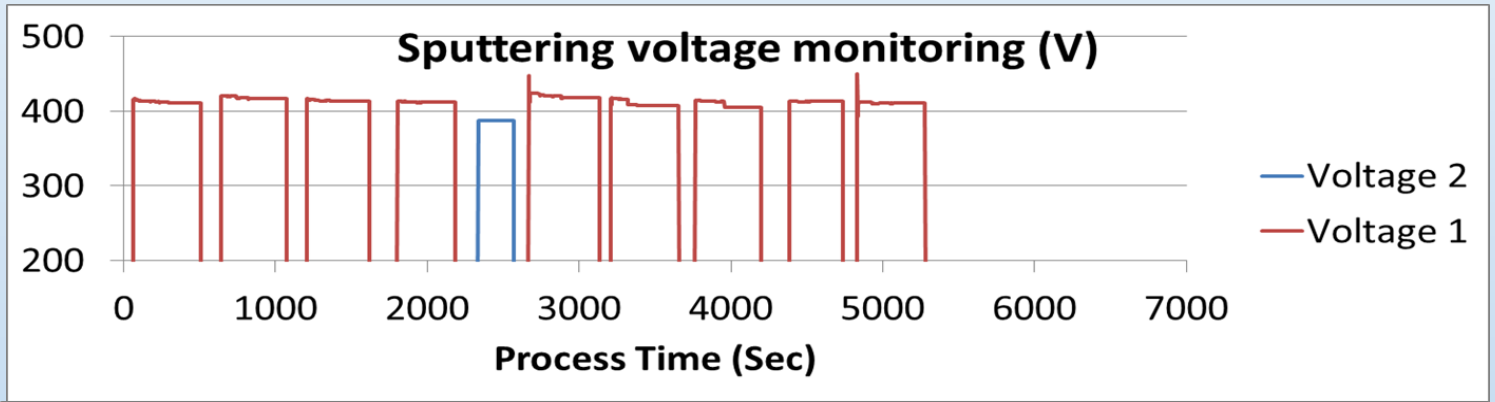
- Ten Million $ equipment will limit most people from the research
- Combinatorial sputter deposition equipment
  - High quality
  - High throughput

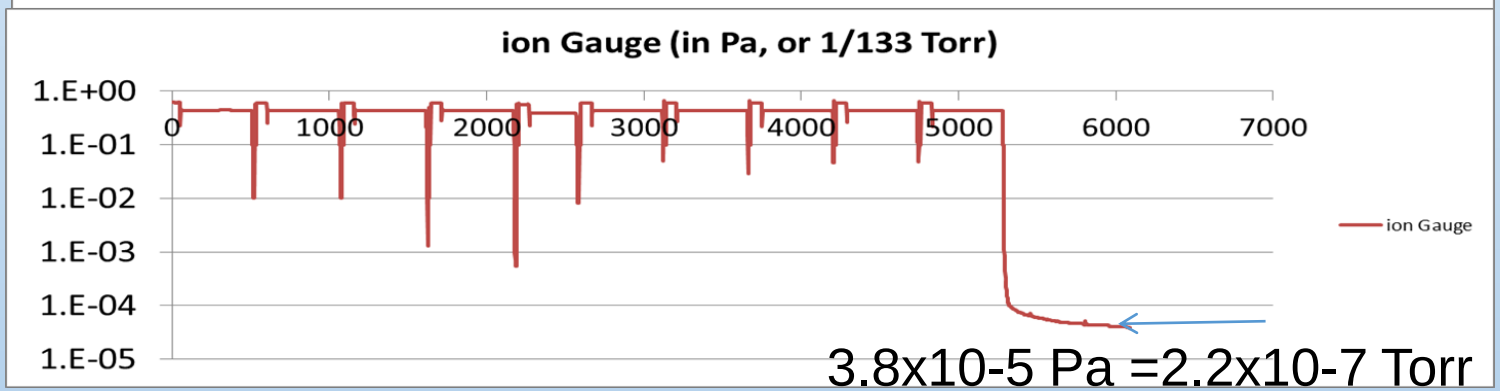
http://www.semicat.com/about_us

What if Reduce cost 100 times?

High quality thin Film Research PVD

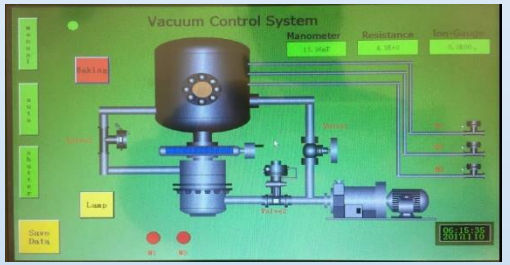
- High quality sputter deposition
  - Background vacuum 9x10^{-8} Torr
  - Independent three Pulsed DC sputtering
- Friendly operation interface
  - Automatic run with programed recipe
  - Experimental parameters can be monitored and recorded.



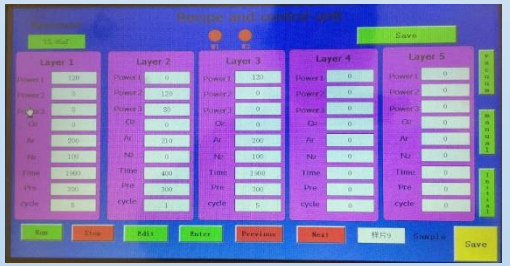


3.8x10-5 Pa =2.2x10-7 Torr

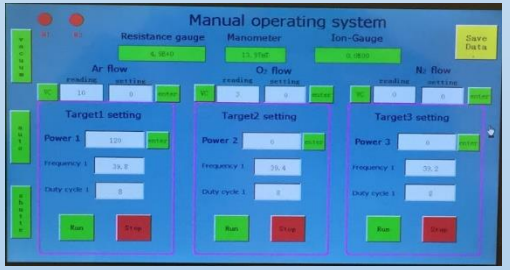
Vacuum interface



Recipe interface



operation interface

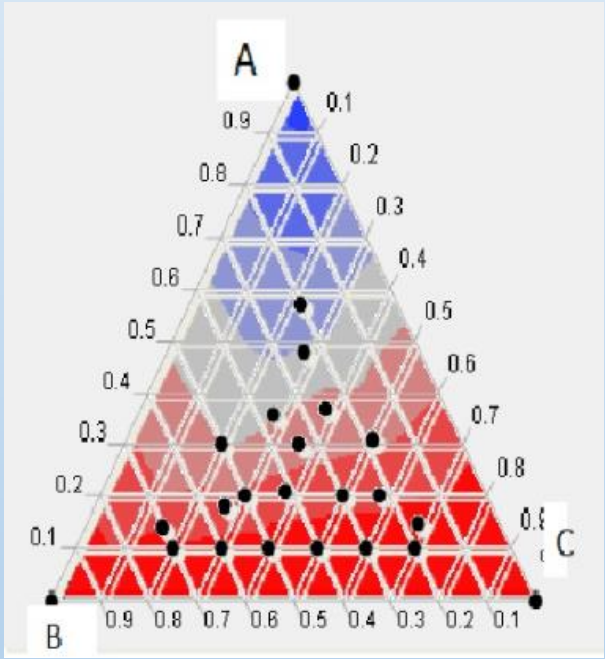


High Quality Extensive New Materials Research Capability

- Capability to co-sputter and deposit stacks
  - Metals
  - Alloys
  - Metal nitrides
  - Metal oxides

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	74 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn

Workable elements



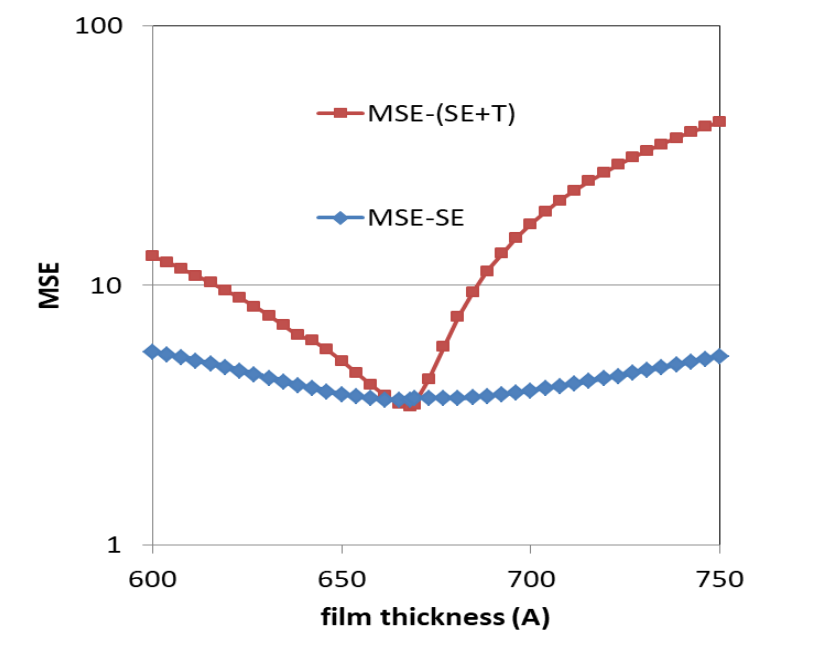
Affordable high quality characterization facilities

- World class metrology available on-site:
  - **Spectroscopic Ellipsometry**
    - Refractive index n, k, as well as film gradient
    - Single layer films / multiple layers stacks
  - **Optical UV-VIS-IR spectra (200nm-2500nm)**
    - Transmission , reflection and absorption
  - **Unique Optical Reverse Engineering and Software**
  - **Electrical Sheet Resistance, Carrier density and mobility**
  - **More characterization available on site with a partner**
    - **AFM**
    - **XRD/XRR**
    - **Optical profilometer**
    - **SEM**

High quality data :Unique Optical Reverse-Engineering.

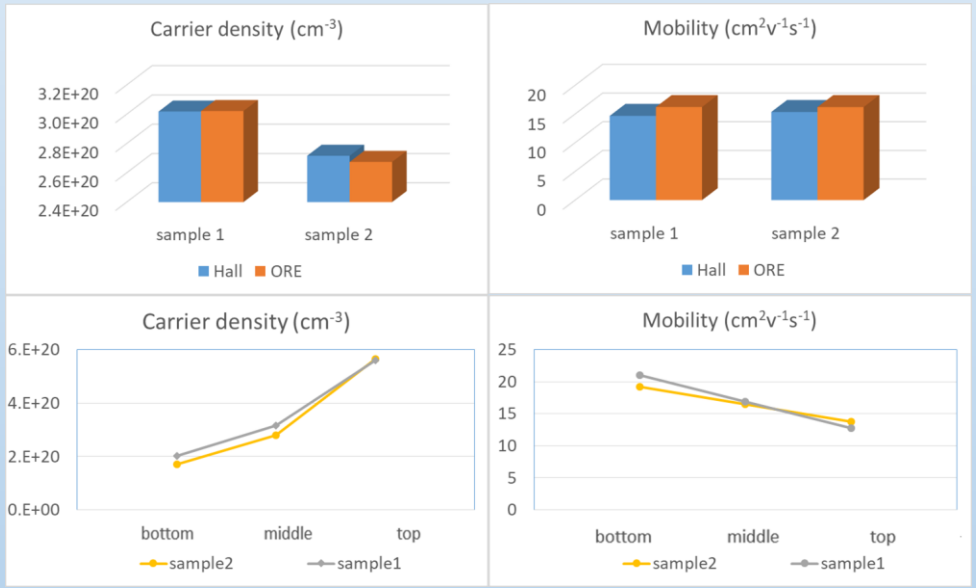
The more measurements + Software ➔ higher accuracy➔ more analysis information

- **Ellipsometetry (SE) + Transmittant(T)**
  - Much more accurate n,k , thickness
  - Gradient along thickness direction



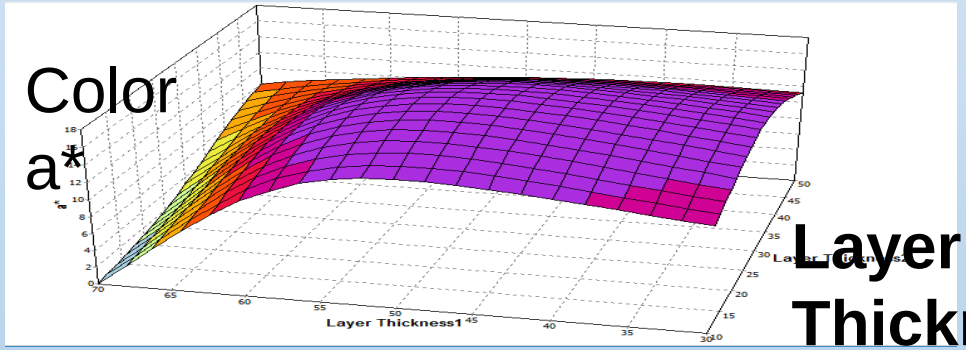
- **SE + Trans. + Refl. + R (sheet resistance)**
  - More accurate thickness, n, k,
  - More information: Gradient, carrier density, mobility …

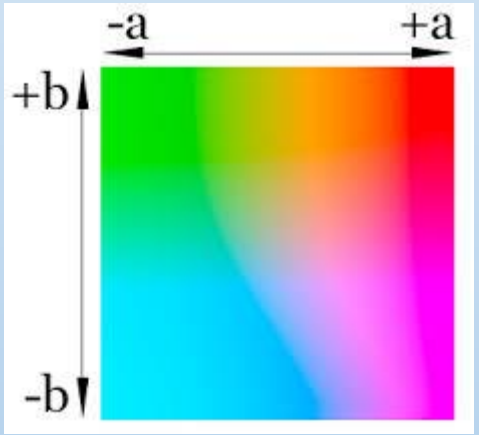
Carrier Density and Mobility by Ellipsometry (SE) + Transmittance (T) + sheet resistance (R)



Software overcomes the knowledge barrier reduces the research time and cycles

- Optical prototype product research
  - No need for years training any more (no PHD degree is OK)
  - No need for extensive DOEs any more (cost significantly reduced)
    - As long as the model design results meet the spec, nearly 90% post deposition film can meet the spec
- Researchers can focus their research goal, reduce knowledge / process barrier.





Example of an optical coating spec

Measured data for as-coated and heat-treated stacks

			AC	HT
Monolithic Optics (III 'C', 2 deg obs)	T	Y (%)	79.1	82.2
		a*	−6.25	−5.60
		b*	0.94	1.25
	Rg	Y (%)	5.51	5.91
		a*	9.26	8.22
		b*	−4.96	−4.37
	Rf	Y (%)	4.67	5.46
		a*	8.07	10.46
		b*	3.94	1.40
	A[vis] (100-TT-Rf)		16.2	12.4
IGU Optics (III 'C', 2 deg obs)	T	Y (%)	71.7	74.5
		a*	−6.64	−5.98
		b*	1.05	1.32
	Rg	Y (%)	10.70	11.50
		a*	3.25	2.78
		b*	−3.09	−2.53
	Rf	Y (%)	12.00	12.60
		a*	3.10	4.51
		b*	1.22	0.24
Normal Emissivity (EN)			0.019	0.007
Haze (%)			0.17	0.58
HT – AC	Rg ΔE*			1.6
	T ΔE*			1.5
	T |Δb*|			0.3
	T ΔY % (HT > AC)			3.1
NFRC 2001 Thermal Performance	Tvis (%)		32	33.6
	Tsol (%)		71.8	74.6
	SHGC(3)		0.235	0.228
	SHGC(2)		0.428	0.425
	Uval		0.345	0.36
	LSG(3)		1.68	1.75
	LSG(2)		2.08	2.07

*US patent :US 2014/0272354 A1

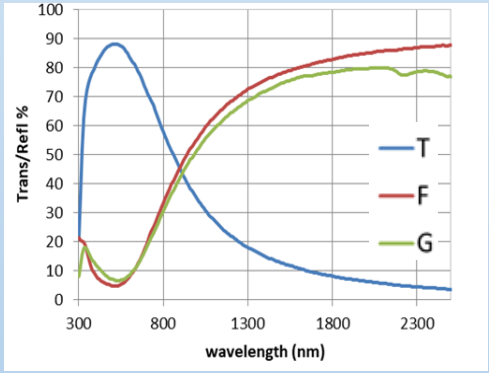
Workflow: Fast Research Cycle

Glass Substrate

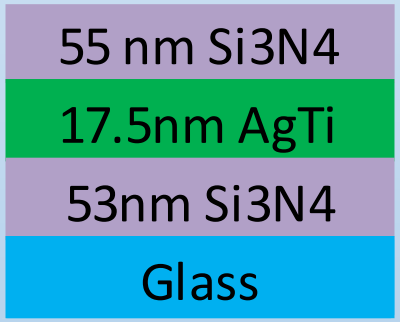
Combinatorial deposition
Stack
New materials

Metrology: Optical and Electrical, Thermal

Revers Engineering



New Model Design



New DOE based Model design

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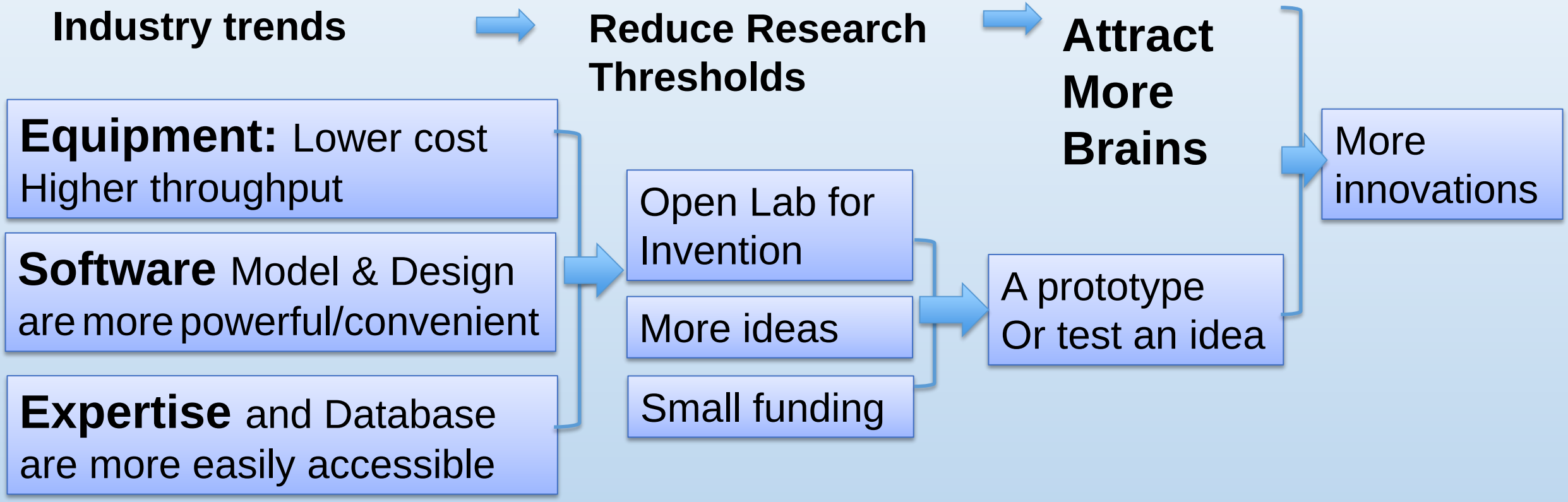
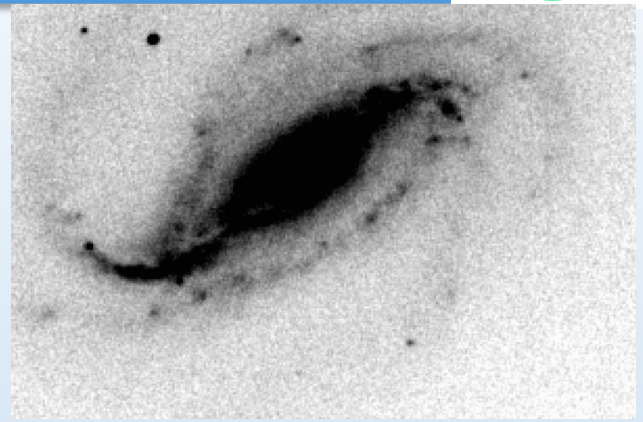
Unique quick screening/prototyping optical products

- How fast is fast?
- Is that possible to finish a patent alert or a publication in two weeks?
- Average less than 2 weeks for a patent alert?

Trends for More Innovations



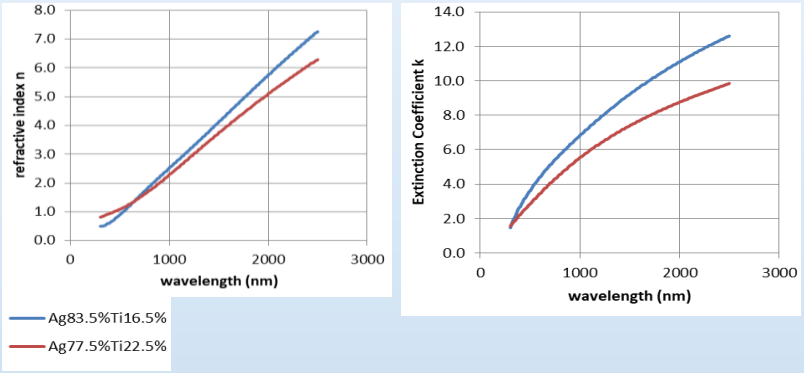
A new path for more innovations

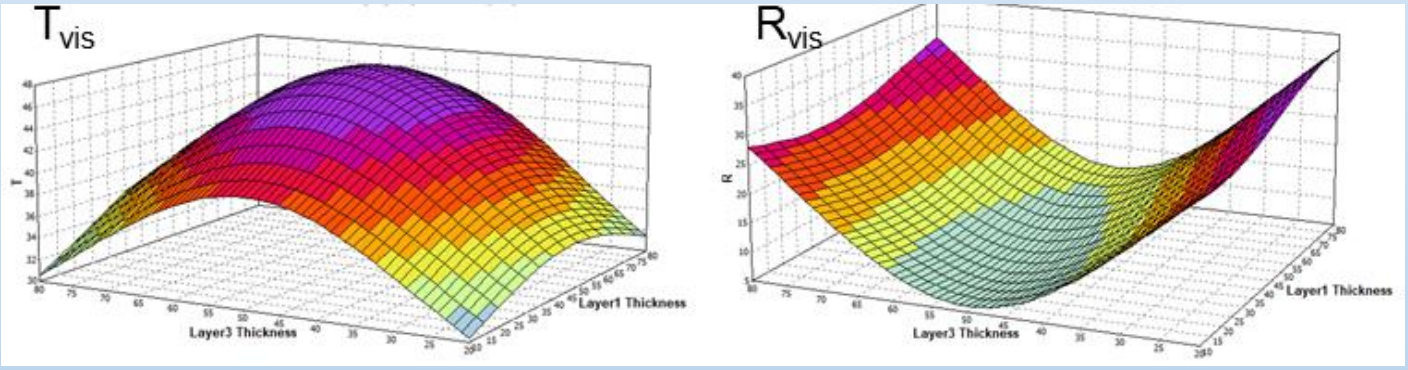


- Today this was a news: “Amateur astronomer catches first glimpses of birth of a supernova”
- Could optical materials research is common as amateur astronomers someday ?
- The threshold for optical research is significantly reduced now,
  - **Anyone who has a dream of innovation, could spend his effort, could achieve some prototypes, patents, publications, by a new lab service.**
  - Tens of thousand $ is possible for a project
    - A family, rather than a company is possible for a research funding by a personal reason
    - A research director, without a complicated funding applications, could decide a small funding
- Affordable Lab ➔more brains, ➔better ideas,➔ more innovations.

Case study 1 : Co-sputtering for new materials / Optical coating optimization development

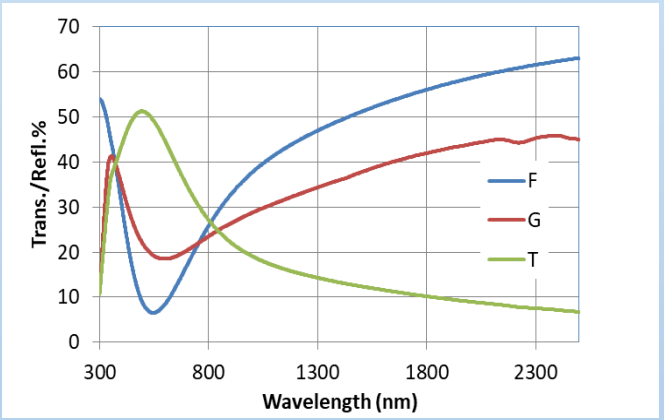
- **New materials Ag_xTi_y research and characterization**





- **Designing an energy saving product with the new materials**
  - **High performance product**
  - **Publication was done in 2 weeks**

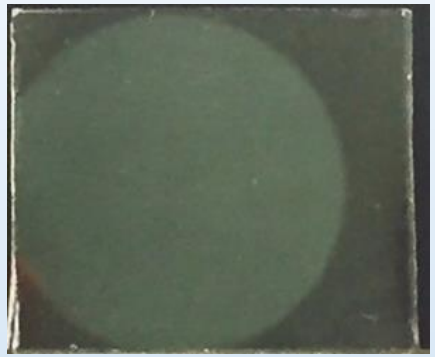
Layer 3: SiN_x	72 nm
Layer 2: AgTi	17.5 nm
Layer 1: SiN_x	12 nm
Glass substrate	3 mm



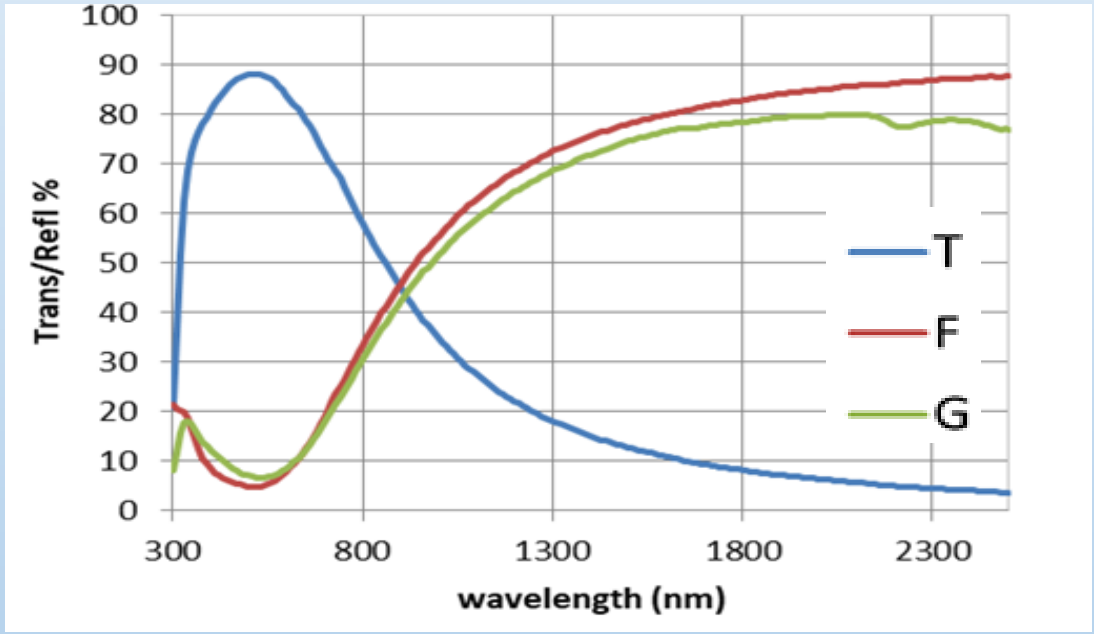
Published: G. Ding and T. Lu, 8th International Conference and Exhibition on Lasers, Optics & Photonics, Nov. 2017, USA

Case study 2: High transmittance energy saving window coating product development

- A publication was finished in less than 2 weeks.
- High transmittance low-E coating obtained, matches high transmittance low-E performance
  - Coated glass T_{vis}: 86%
  - Insulating Glass Units Performance:
    - T_{vis}: 79.0%
    - Light-to-Solar Gain: 1.51



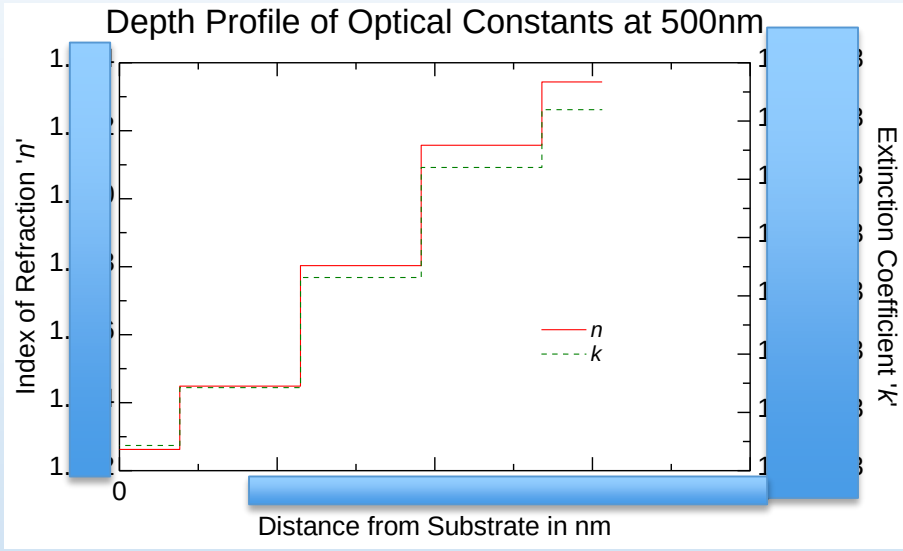
Layer 3:	SiN_x	45 nm
Layer 2:	AgX	13 nm
Layer 1:	SiN_x	45 nm
Glass substrate		3 mm



Results published:
Zhou et al., 14th International Conference and Exhibition on Materials Science and Engineering, Nov. 2017, USA

Case 3 Trouble-shooting customer issues

- There is a color issue in a customer coating
- We did Optical Reverse Engineering which indicated that there was a metal migration into another layer by xx%.
- Research on a new barrier material
  - Software Designs a new coating stack
  - PVD deposition
- ➔ Resolve the color issue



Summary

- The future research trends on faster, cheaper, better solutions as the trends of Moore's law.
- There will be a point in time when the research threshold is so low that attract more brains, with more ideas for more innovations.
- Labforinvention is such a Laboratory with a mission of better, faster cheaper solutions for thin film research.
- "Optical coating innovation is accessible, affordable, and open to everyone who want to have an innovation", is closer to the reality.

- Thanks to our partner, Covalent Metrology, better, faster and cheaper data for every client
- Thanks for your attentions